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Antioxidant Activity of Sweet Potato Based Tapai: Experimental Study on Different Varieties and Fermentation Duration

Yuliana Yuliana[a]*, Mansyur Mansyur[b], Urras Naleluni[b]

Abstract. Free radicals caused by modern living are linked to diseases like cancer, diabetes and heart disease. Antioxidants in food, such as sweet potatoes, are a safe way to prevent these. Sweet potatoes have lots of bioactive compounds, especially in the purple and yellow types. Fermentation, like in tapai made from sweet potatoes, can make antioxidants more active by changing phenolic compounds. The present study evaluated the antioxidant activity of different sweet potato types (purple, yellow, and white) at various fermentation durations. Sweet potatoes were fermented for 0, 2, 4 or 6 days and the antioxidant activity of the resulting tapai was measured using the DPPH method. The study found purple sweet potato tapai fermented for four days to have the highest antioxidant activity, with an IC_{50} value of 52.7 µg/mL, almost reached vitamin C at IC_{50} 45.6 µg/mL. Yellow and white sweet potato tapai showed much lower activity (IC_{50} 68.4 and 83.1 µg/mL, respectively). The study showed antioxidant levels can vary depending on sweet potato variety and fermentation time. These findings contribute to the development of traditional fermented foods as a preventative dietary intervention against degenerative diseases, which are increasingly prevalent in modern society.

Keywords : Sweet potato tapai, fermentation, functional food, antioxidant, IC_{50}.

[a]*Department of Chemistry, Faculty of Mathematic and Natural Science, Universitas Palangka Raya, Palangka Raya 74874, Central Kalimantan, Indonesia*
[b]*Department of Biology Education, Faculty of Teacher Training and Education, Universitas Palangka Raya, Palangka Raya 74874, Central Kalimantan, Indonesia.*
Correspondence and requests for materials should be addressed to Yuliana
(email: yuliana@mipa.upr.ac.id)

Introduction

Degenerative diseases such as cancer, diabetes mellitus, and coronary heart disease are increasing in prevalence on a global scale. According to the World Health Organization (2023), approximately 74% of all global deaths are attributable to non-communicable diseases, the majority of which are associated with oxidative stress arising from elevated levels of free radicals within the body [1]. A significant prevention strategy involves the ingestion of foods abundant in natural antioxidants. Antioxidant compounds have been demonstrated to counteract the negative effects of free radicals, prevent cell damage, and slow down the aging process of cells [2-3]. Consequently, the search and utilization of local foods as a source of natural antioxidants is a primary focus in the field of functional food and public health.

Sweet potato (Ipomoea batatas) is a staple food in Indonesia, and it is a rich source of bioactive compounds, including anthocyanins, β-carotene, vitamin C, and polyphenols, which act as antioxidants. According to Statistics Indonesia (2023), national sweet potato production in 2022 exceeded 2 million ton, thus classifying it as an abundant and strategic commodity [4]. In Indonesia, sweet potatoes are consumed not only in their fresh form, but also in the form of tapai, which is produced through a traditional fermentation process. Fermentation increases the bioavailability and antioxidant activity of bioactive compounds through the bioconversion process catalyzed by microorganisms such as Saccharomyces cerevisiae and Lactobacillus plantarum [5]. However, the effect of fermentation on the antioxidant capacity of different sweet potato types has rarely been studied. Several precious studies have demonstrated that the fermentation process can enhance the antioxidant activity of certain food ingredients. Hidayat et al. (2020) reported an increase in antioxidant capacity of between 30 and 40% in cassava tapai following a 72-hour fermentation process. Research by Yuliana and Fitriani (2021) revealed that purple sweet potato tapai exhibited higher antioxidant activity in comparison to yellow sweet potato tapai. However, the study has not yet made a comprehensive comparison of the antioxidant activity of several sweet potato varieties (e.g. purple, yellow, and white sweet potatoes) in the post-fermentation context [6-7].

The lack of research findings is evident from the limited information available on the relationship between the color characteristics of sweet potatoes (a vegetable containing certain bioactive compounds) and their antioxidant activity during fermentation. A study comparing data from a range of sweet potato varieties with different fermentation times and antioxidant assessment methods is required. This information is crucial for determining the most effective type of sweet potato for functional use, thereby substantiating the scientific rationale for the functional assessment of fermented sweet potato. This study aims to evaluate the antioxidant activity of different types of sweet potato tapai (purple, yellow and white) using an experimental approach involving variations in fermentation time, with results measured using the DPPH method. The results are expected to contribute to the development of functional foods based on local resources and encourage an increase in the added value of sweet potato tapai products as healthy traditional foods. Additionally, this research is expected to fill the literature gap related to the comparison of the antioxidant capacity of tapai from various sweet potato varieties.

Experimental

This research involved laboratory experiments with a factorial design and a completely randomized design (CRD). It was conducted to examine the effect of sweet potato types (purple, yellow and white) and fermentation duration (0, 2, 4 and 6 days) on the antioxidant activity of sweet potato tapai. Materials consist of purple, yellow, and white sweet potato varieties obtained from traditional market in Palangka Raya, tapai yeast merk NKL, DPPH (2,2-diphenyl-1-picrylhydrazyl), ascorbic acid, ethanol, distilled water, and other pro-analysis chemicals.

Fermentation Conditions. The sweet potatoes were washed, cut into small pieces and steamed for 20 minutes before being cooled. Tapai yeast was inoculated onto the surface of the steamed sweet potatoes by spreading it thinly (0,5% of the weight of the material) [8]. The sweet potatoes were then fermented in a closed container covered by banana leaf at room temperature for 0, 2, 4 and 6 days, depending on the treatment.

Extraction of Tapai. The sweet potato tapai from each treatment were dried and mashed, then extracted using a 96% ethanol via the maceration method for 24 hours. The filtrate was filtered and the solvent evaporated.

Antioxidant Activity. Tapai extracts of various types of sweet potato were dissolved at varying concentrations. Subsequently, the samples were added to a 0.1 mM DPPH solution. The mixture was then subjected to an incubation period of 30 minutes in conditions of darkness. Subsequently, the absorbances were measured at a wavelength of 517 nm, employing a UV-Vis spectrophotometer [9]. The antioxidant activity was calculated based on the percentage of DPPH radical scavenging, and IC50 values were determined to assess antioxidant capacity.

Data Analysis. The data obtained were analyzed statistically using a two-way ANOVA to determine the effects of sweet potato type and fermentation time on antioxidant activity. Further analysis was performed using the Tukey–Kramer honestly significant difference (HSD) test at a significance level of 5% to determine the differences between the treatments. The IC_{50} calculation was performed using linear regression from the % inhibition vs. concentration curve.

Result and Discussion

Sweet potatoes exhibit a variety of nutritional components, which are determined by their specific variety. The nutritional composition of purple sweet potato (*Ipomoea batatas* L.) comprises 123 calories, 27.9 grams of carbohydrate, 1.8 grams of protein, 1.2 grams of fiber, 0.7 grams of fat, 68.5 grams of water, and 110.51 milligrams of anthocyanin. Conversely, 100 g of yellow sweet potato contains 136 calories, 32.3 g of carbohydrates, 1.1 g of protein, 1.4 g of fiber, 0.4 g of fat, 71.2 g of water, and 114 mg of β-carotene. Conversely, 100 g of white sweet potato contains 123 calories, 27.9 g of carbohydrate, 1.8 g of protein, 0.9 g of fiber, 0.7 g of fat, 68.5 g of water, and 114 mg of β-carotene [10]. The chemical composition of sweet potatoes, particularly its pigment content, has been demonstrated to influence its antioxidant activity.

Characteristic of tapai's ethanol extract. Fermentation of various types of sweet potatoes (purple, yellow, and white) produces a beverage known as tapai, which is characterized by an approximate pH of 5, sweet taste, soft texture, and sweet aroma with a hint of alcohol. The extraction results of different types of sweet potato tapai also show a variation in color (Figure 1). The extraction process yielded a purple extract from the purple sweet potato sample, an orange-colored extract from the yellow sweet potato sample, and a yellowish-white extract from the white sweet potato sample. The variation in color of the tapai extract in sweet potato is determined by its pigment content. In the case of purple sweet potato, the dominant pigment is anthocyanin, a natural water-soluble pigment that is colored red, purple and blue in certain fruits and vegetables. The visible color of anthocyanins is influenced by their long conjugated double bond arrangement, which allows them to absorb light over a wide range of visible light. Anthocyanins are a group of flavonoid compounds that have bioactivities such as antioxidants, anti-inflammatory, anti-cancer, cardiovascular disease and diabetes prevention, and improvement of brain function [11]. Meanwhile, β-carotene, a provitamin A carotenoid, is found in yellow sweet potatoes. β-carotene is a natural pigment found in a variety of yellow, orange and red fruits and vegetables. It is a precursor to vitamin A and is an organic compound, chemically classified as a hydrocarbon and specifically classified as a terpenoid (isoprenoid). β-carotene is classified as a hydrocarbon compound, specifically a terpenoid (isoprenoid), distinguished by the presence of beta rings at both ends of the molecule [12]. These compounds function as antioxidants and support ocular, dermal and immune system health. In contrast, white sweet potatoes contain significantly lower levels of anthocyanins and β-carotene when compared to their purple and yellow variants. This results in a yellowish white coloration.

Antioxidant activity of tapai. The findings indicated that the variety of sweet potatoes and the duration of fermentation significantly influenced tapai's antioxidant activity, as measured by the DPPH method. The antioxidant activity is expressed

Figure 1. The color of ethanol extracts of tapai on different sweet potato types

as the IC_{50} value, which is defined as the concentration of the extract required to reduce 50% of the DPPH free radicals. A small IC_{50} value indicates high antioxidant activity. A 2-way ANOVA test revealed significant effects ($p<0.05$) of sweet potato type, fermentation duration, and their interaction on the antioxidant activity of the tapai. The IC_{50} value of purple sweet potato tapai was found to be the lowest in comparison to that of yellow and white sweet potato tapai. On the fourth day of fermentation, purple sweet potato tapai demonstrated the highest antioxidant activity, with an IC_{50} value of 52.7 µg/mL. In contrast, yellow and white sweet potato tapai exhibited IC_{50} values of 69.4 µg/mL and 83.1 µg/mL, respectively, at the same fermentation time. The IC_{50} value of purple sweet potato tapai is comparable to the antioxidant activity of vitamin C (IC_{50} 45.6 µg/mL), which was utilized as a positive control. This finding correlates with the observations reported by Putri et al. (2021), who established a correlation between high anthocyanin content and the presence of total phenols and flavonoids, which contribute to the enhancement of the antioxidant effect. Consequently, the tapai produced from purple sweet potato has been found to exhibit higher antioxidant activity compared to other varieties [13].

The fermentation time also had a significant effect. Antioxidant activity increased with fermentation time until day 4 but subsequently decreased after day 6. Fermentation for a period of 2-4 days has been shown to increase antioxidant activity, due to the breakdown of complex compounds into more active free phenolic forms by enzymatic processes carried out by microorganisms, such as Saccharomyces cerevisiae. Fermentation on day 4 resulted in the lowest IC_{50}, signifying the highest antioxidant activity [14]. A decrease in antioxidant activity was observed on the sixth day may be caused by the degradation of phenolic compounds due to excessive enzymatic activity or the accumulation of metabolic by-products that inhibit the activity of antioxidant compounds. A similar study by Hidayat et al. (2020) also showed that the antioxidant capacity of cassava tapai increased until the 3rd day of fermentation, then decreased due to the degradation of bioactive compounds [6]. This demonstrates the significance of optimizing fermentation time to obtain maximum functional activity from fermented products. Tapai from white sweet potato consistently exhibited the lowest antioxidant activity. This phenomenon is attributed to the lower levels of anthocyanins and β-carotene, present in white sweet potato compared to its purple and yellow variants.

Based on literature data, the total phenol content in purple sweet potato ranges from approximately 140-170 mg GAE/100g, while yellow sweet potato ranges from approximately 90-110 mg GAE/100g, and white sweet potato ranges from approximately 50-60 mg GAE/100g [15]. The bioactive content (e.g. anthocyanins, flavonoids, total phenolic compounds) determines the antioxidant capacity of the tapai. It has been shown that bioactive compounds have the capacity to capture free radicals and inhibit cell oxidation processes. Research by Ayuningtyas et al. (2020) showed a significant positive correlation between total phenolics and antioxidant capacity in sweet potato [16-17]. In the context of tapai, fermentation increases the solubility of these phenolic compounds, but the quality depends on the raw materials' content. This low phenolic compound has been shown to limit the antioxidant potential of white sweet potato tapai, despite the tapai being fermented for the same amount of time.

Temperature and humidity levels during the fermentation process also affect yeast metabolic activity and stability of bioactive compounds. Optimal fermentation occurs at a temperature of 27-30° C, where yeast enzymes are most active. Excessive heat can lead to the inactivation of enzymes and the degradation of phenolic compounds. Conversely, insufficient heat can result in a reduction in the rate of fermentation and bioactivation processes [18-19].

These results support the hypothesis that sweet potato type significantly affects the antioxi-

Table 1. IC_{50} (µg/mL) values of different sweet potato types and fermentation duration

Types	Day 0	Day 2	Day 4	Day 6
Purple	98.3 ± 1.9^{d}	67.2 ± 2.1^{b}	**52.7 ± 1.4^{a}**	61.5 ± 2.0^{bc}
Yellow	115.4 ± 2.6^{e}	83.9 ± 2.7^{c}	**69.4 ± 1.8^{b}**	75.8 ± 2.3^{bc}
White	127.1 ± 3.0^{f}	98.2 ± 2.5^{d}	**83.1 ± 2.2^{c}**	89.5 ± 2.7^{c}
Vitamin C	45.6 ± 1.5^{a}	nd	nd	nd

Data are presented as mean ± standard deviation of three repetitions (n=3). Different letter notations in the same column indicate statistically significant differences ($p < 0.05$) based on Tukey HSD further test.

dant capacity of post-fermentation tapai, with purple sweet potato having the greatest potential for development as a functional food due to its high phenolic content coupled with a robust fermentative response. Fermentation process, lasting four days, was identified as the optimal condition to enhance the bioavailability of antioxidant compounds without inducing substantial degradation. Research by Widyaningsih and Astuti (2022) also observed the highest increase in antioxidant capacity in 4-day fermented purple sweet potato tapai, with a positive correlation to total anthocyanin content [14].

Conclusion

The present study showed effectiveness of antioxidant activity in tapai depends on variety and fermentation duration. Purple sweet potato tapai (fermented 4 days) had the best activity with IC_{50} value 52.7 µg/mL), followed by yellow and white sweet potato tapai (IC_{50} = 68.4 and 83.1 µg/mL). The findings have the potential to be developed as a healthy traditional functional food compared to consuming synthetic supplements.

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Author Contributions

The research was designed and supervised by Yuliana, who also wrote the article, while two other students (Mansyur and Urras Naluleni) carried out the laboratory experiments as an implementation of Project Based Learning for Biotechnology course.

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